Sediments in stormwater and streams: Investigating industry and academic insights and opportunities for future research

Les sédiments dans les eaux pluviales et cours d'eau : enquête sur les perspectives industrielles et académiques, et opportunités pour de futures recherches

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RÉSUMÉ

Au cours des dernières décennies, nos efforts se sont concentrés sur la gestion quantitative et qualitative des eaux pluviales atteignant les rivières et cours d'eau. De ce fait les sédiments provenant des eaux de ruissellement des villes et banlieues sont devenus des «prises accessoires» dans les mesures de contrôle des eaux pluviales (SCM). Cela a conduit à reconnaître de manière croissante les efforts de gestion et les coûts supplémentaires pour les municipalités et autorités liés à la gestion des sédiments dans les cours d'eau et voies navigables, telle que l'élimination coûteuse des sédiments reconnus comme contaminés. La rétention sédimentaire peut aussi affecter la justesse des SCMs et a des conséquences sur les cours d'eau dans les bassins hydrographiques qui ont un apport de sédiments modifiés. L'ampleur du problème est cependant mal comprise. Pour examiner ces questions, nous avons effectué une revue littéraire et tenu un atelier avec des représentants de municipalités, autorités et milieux universitaires des villes australiennes de Melbourne, Sydney et Brisbane, et un représentant du Kentucky aux États-Unis. L'étude a reconnu plusieurs lacunes d'un point de vue littéraire, en particulier un manque de données concernant les niveaux de sédiments et leurs contaminants. L'atelier a quant à lui déterminé que les municipalités et autorités australiennes et internationales sont confrontées à des défis similaires en ce qui concerne la gestion des sédiments dans les cours d'eau urbains et les mesures de contrôle des eaux pluviales ; notamment en ce qui concerne le coût d'entretien et d'élimination. Cette étude donne un nouvel aperçu des défis importants liés à la gestion des sédiments dans les cours d'eau urbains et les mesures de contrôle des eaux pluviales, met en évidence certaines opportunités et fournit une plateforme pour de futures collaborations dans le domaine de la recherche.

ABSTRACT

The last few decades has seen a focus on managing the quantity and quality of stormwater reaching receiving streams. In doing so sediment in the runoff from cities and suburbs has become a 'by-catch' in stormwater control measures (SCMs). This has led to increasing recognition of the added management effort and costs for councils and authorities associated with managing sediment in SCMs and waterways, such as costly disposal of sediments classed as contaminated. Sediment trapping can also impede function of SCMs and has implications for waterways in established urban catchments that have altered sediment supply. The magnitude and scale of this problem, however, is poorly understood. To investigate these issues we conducted a literature review and facilitated a workshop with representatives from councils, authorities and academia from the Australian cities of Melbourne, Sydney and Brisbane, and a representative from Kentucky, United States. The study identified multiple knowledge gaps in the literature, in particular the availability of data about sediment loads and associated contaminants. The workshop discussions determined that councils and authorities across Australia, and internationally, are dealing with similar challenges in relation to sediment management in SCMs and urban waterways; particularly in regard to the cost of maintenance and disposal. This study provides new insight into the significant challenges associated with sediment management in urban streams and SCMs, highlights some opportunities and provides a platform for further research collaboration in the future.

KEYWORDS

Cost, maintenance, sediment, stormwater, stormwater control measures, urban streams

1 INTRODUCTION

Impacts on the geomorphic and ecological attributes of streams arising from urban-induced changes to hydrologic regimes are well-documented (Walsh et al., 2005, Gurnell et al., 2007, Paul and Meyer, 2001). However, urbanisation influences not only water, but also the supply and delivery of coarse-grained (bedload) sediments to streams (Vietz et al., 2012, Gregory, 2006). Recent work by Vietz et al. (2014) has demonstrated just how sensitive stream geomorphology can be to even low levels of urbanization. There is also growing recognition of the impact contaminated sediment has on stream health, and surprisingly, the lack of coarse-grained sediments in stream channels, which are vital to the protection and recovery of urban streams (Vietz et al., 2012).

In recent decades, recognition of the detrimental impact urban stormwater has on humans and aquatic ecosystems has led to a shift away from traditional approaches to urban drainage, focused on quantity issues for flood mitigation, towards a more holistic vision of 'water sensitive urban design' (WSUD) (synonymous with LID, see Fletcher et al. (2014)), which aims to provide multi-faceted benefits to environments and society (Victorian Stormwater Committee, 1999, Lloyd et al., 2002, Wong and Eadie, 2000). In Australia, and many cities worldwide, urban planners and designers are applying WSUD principles to design water sensitive cities that incorporate physically and ecologically healthy waterways.

Removal of contaminated sediment from stormwater runoff is a key priority in this regard. For instance, in Victoria, Australia, stormwater load reduction targets require stormwater control measures (SCMs) to reduce total suspended solid loads by at least 80% (Victorian Stormwater Committee, 1999). However, these guidelines do not specify the fraction of sediment to be removed. As such, structural stormwater control measures (SCMs) do not typically discriminate between removal of fine- and coarse-grained sediment. This overlooks the fact fine-grained sediments (silt and clay) are largely responsible for the contamination and morphological impacts associated with sediment (Houshmand et al., 2014). Moreover, the reduction of coarse-grained sediment (e.g. sands, gravels etc.) supply to streams has negative consequences for aquatic ecosystems, including reduced foraging and refuge for macroinvertebrates and fish (Paul and Meyer, 2001, Walsh et al., 2001, Gurnell et al., 2007). Consequently, current approaches to improving stormwater quality and quantity may not be satisfying the healthy waterway objectives of WSUD

A perhaps more immediate consequence is that accumulation of sediment in SCMs now presents a major challenge for asset managers due to mounting maintenance requirements to ensure ongoing treatment effectiveness of SCMs and costs associated with the removal and disposal of contaminated sediments. For example, Melbourne's water authority currently spends more than $6 million per year on the removal, treatment and disposal of sediment from urban streams and detention basins, much of which is contaminated. In a more extreme case a single sediment removal project in Cooks Rivers, Sydney, cost $6 million. These costs, however, have not previously been tallied.

The present paper presents key issues and knowledge gaps with regard to understanding sediment transport in urban catchments and explores challenges and opportunities for better management of sediment in SCMs and urban streams. Understanding these issues is paramount to protecting urban streams, and the ecological and social values they provide, and to building water sensitive cities.

2 METHODS

We undertook a two-pronged scoping study to investigate the challenges and opportunities for the management of sediment in SCMs and waterways in urban catchments. Firstly, we critically reviewed the academic and grey literature from sources internationally using web of science and Google scholar as a basis. Secondly, we conducted a workshop incorporating representatives from councils, authorities and academia from Melbourne, Sydney and Brisbane, Australia, as well as a representative from Kentucky, United States, to discuss issues in understanding and managing urban sediment. In both settings we posed questions such as: What are the costs associated with sediment management in SCMs and waterways in urban catchments? Should we be managing fine-grained and coarse-grained sediments differently? What is the association between contaminant transport and sediments? How do changes to the sediment supply impact on SCMs and waterways in urban catchments? What are the opportunities for sediment considerate design of SCMs to reduce management effort and improve the condition of receiving waters? We note some key findings here in this short communication.

3 RESULTS

3.1 Costs associated with sediment management

Amongst the findings was quantification of the significant cost implications for authorities of removing sediments from SCMs and waterways. For example, Sydney's water authority spends $3-4 million per year on sediment management from waterways and stormwater systems, and many councils spend more than $1 million annually. From the data received we estimate that Australia-wide costs would be in excess of $100 million. Some suggested these costs would triple within the next decade, commensurate with the implementation of WSUD systems.

Designs for stormwater control measures commonly consider fine-grained sediments (silts/clays), but coarser sediment such as sands and gravels are often the bulk of the sediment to be disposed. Much of this coarse-grained sediment is imported into the catchment for construction purposes and conveyed to the stormwater system by runoff to collect in SCMs such as wetlands and gross pollutant traps. This not only increases maintenance but also reduces the effectiveness of SCMs, and can have impacts on downstream waterways. For example, coarse-grained sediment delivery to waterways in urban catchments is not necessarily detrimental as they often have reduced sediment loads and this can impact on habitat availability and recovery potential (Vietz et al., 2016). Furthermore, it is often the fine-grained sediments that bypass SCMs that have bound contaminants such as heavy metals and phosphorous (Houshmand et al., 2014)

3.2 Challenges and Opportunities

There was a general consensus that many opportunities for managing sediment in SCMs and waterways have not been thoroughly considered because the issue is only recently coming to light with the significant increase in implementation of SCMs. It was also considered that the technology was limiting opportunities to reduce maintenance costs and improve environmental benefits in receiving waterways. For example, multiple benefits could be achieved by SCMs capable of treating stormwater runoff while diverting coarse-grained sediments to waterways (e.g. Figure 1)

Table 1 Challenges and opportunities for improving management of sediment in urban streams and stormwater control measures

Challenges	Opportunities
• Poor data on sediment budget in catchments and streams • Poor data on how sediment affects SCMs and associated costs • Uncertainties in improved SCM design and limited experience with sediment separation technologies • Risks associated with reuse or re-direction of contaminated coarse-grained sediment • Cost of retrofitting SCMs for coarse-grained sediment management • Understanding sediment needs for urban streams	• Cost benefits of reduced need for sediment removal and disposal • Positive effect on urban streams • Improved effectiveness of SCM operation • Prolonged SCM lifespan • Resource innovation opportunities such as sediment reuse • Reduced flooding risk associated with blockage of drainage systems • Cultural and regulatory change for sediment management

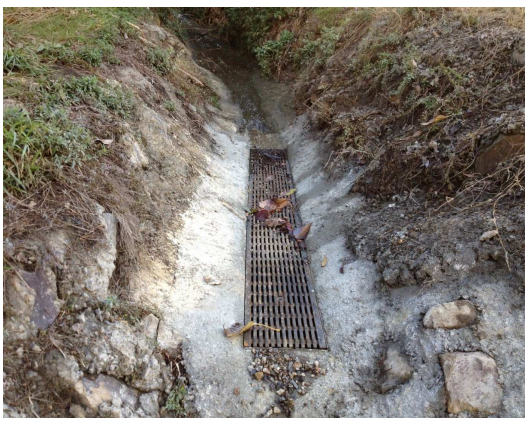

Figure 1 Coarse-grained sediment bypass grate, Mt Evelyn, Victoria, Australia.

4 CONCLUSIONS

With the push for water sensitive cities it is time to reconsider the expensive 'extract and dump' approach to managing sediment in stormwater systems and waterways. We may better achieve goals for an effective and efficient water sensitive city by considering the financial and environmental benefits of holistic and integrated management of sediment by incorporating the notion of a 'sediment sensitive city'. For managers this may result in reduced ongoing maintenance and greater effectiveness of their SCM systems, but it requires greater consideration from the research and development realm.

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